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# *Short Pulses - Accelerator and Optics Perspective*

*George Srajer - X-Ray Science Division*

*APS Upgrade Summary Workshop*

*Argonne, August 11, 2006*

# *Acknowledgements*

## **ASD:**

**Michael Borland**

**Kathy Harkay**

**John Carwardine**

**Ali Nassiri**

**Roger Dejus**

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## **XSD:**

**Sarvjit Shastri**

**Lahsen Assoufid**

**Jin Wang**

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# *Outline*

## **1. Brief History**

## **2. Concept**

**⇒ Deflecting (“crab”) RF cavities**

## **3. Technical Feasibility**

**⇒ RF cavities configurations**

## **4. Beamline Perspective**

## *In the Beginning...*

### **APS Strategic Planning Workshop (Aug 2004): Time Domain Science Using X-Ray Techniques**

*Exploring the possibility of shorter timescales at the APS  $\Rightarrow$  generation of 1 ps x-ray pulses whilst retaining high-flux.*

*This important time domain from 1 ps to 100 ps will provide a unique bridge for science between capabilities at current storage rings and future x-ray FELs.*

#### **Goal:**

- ~1 ps pulses ✓
- Energy tunability ✓
- Flux comparable to 100 ps
- High repetition rate

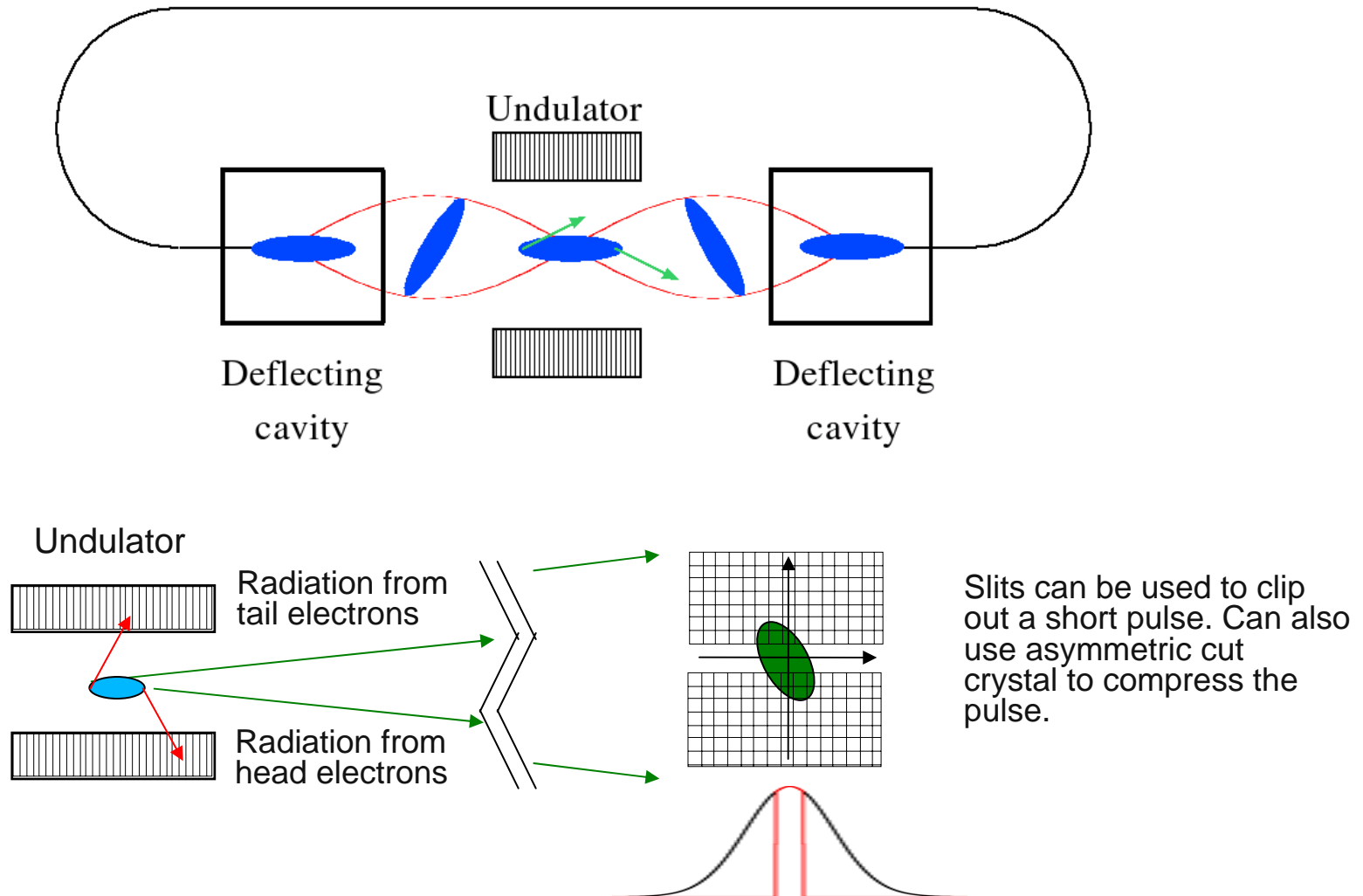
## ***More “In-House” Meetings***

**APS User’s Meeting: Workshop on Generation and Use of Short X-ray Pulses at APS (May 2005)**

**APS Upgrade Planning: Workshop on Picosecond Science (June 2006)**

**⇒ Linda Young to report**

## 2. Concept\*



\* A. Zholents, P. Heimann, M. Zolotarev, J. Byrd, NIM **A425** (1999)

# *Choice of Cavities: Pulsed versus CW*

## **Pulsed\***

- *Cheaper and faster to implement*
- *Cavities are only 0.5 m long and water cooled*
- *Room temperature technology*
- Repetition rate limited to ~ 1 kHz

## **CW**

- *High repetition rate (CW)*
- Cavities are long ~ 2.5 m
- Cryo cooled technology
- Expensive and time-consuming to implement

\*Never done before in a storage ring

*Allen Stewart Königsberg (1935)*

**“We stand at a crossroads: One path leads to despair and  
hopelessness. The other leads to total extinction.**

**Let us hope we have the wisdom to make the right choice.”**



*Pulsed or CW?*

**More sensible to implement the PULSED option**

# *Short Term Implementation of Picosecond Capability\**

## Phase I:

**Offers limited picosecond capability within 12 months**

- ⇒ Rep rate: 120Hz, pulse length: ~few ps, 2.4m undulator*
- ⇒ Hybrid fill pattern, only the 16mA bunch is chirped*
- ⇒ Only one sector affected*

## Phase II:

**Incremental progression to ~1ps source at 1kHz rep rate, and with increased flux (extended straight section)**

**Additional 12 months**

**\*Aggressive schedule not without technical challenges**

## ***Contributing to Fast Track Implementation***

**Some hardware already in house:**

- **Spare linac klystron + modulator (relocate to SR area)**

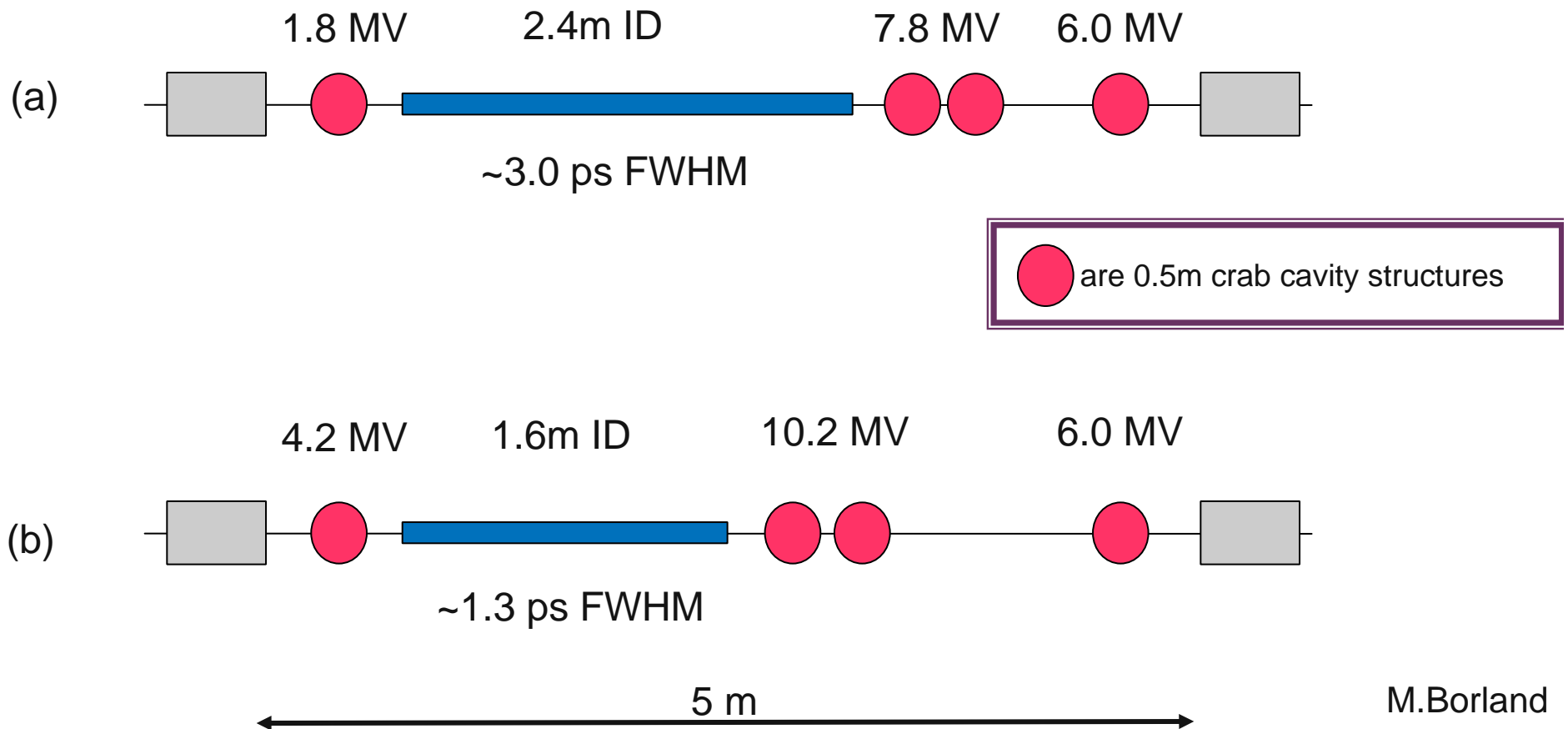
**Other hardware in advanced design phase:**

- **Four new 0.5 m crab cavity structures**

### 3. Proposed Compact (Single Sector) Option

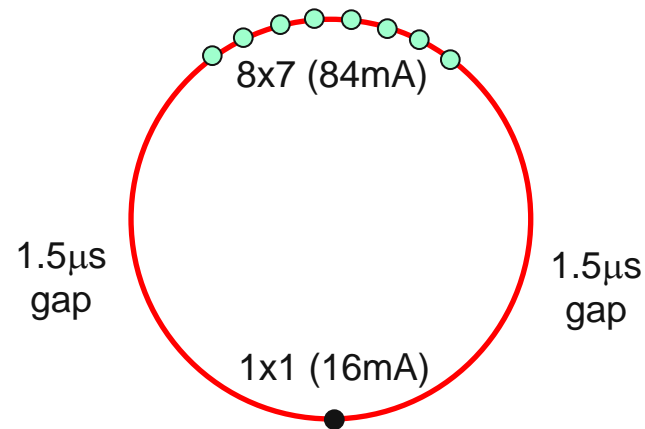
#### Phase I

Standard straight section: 5 m long

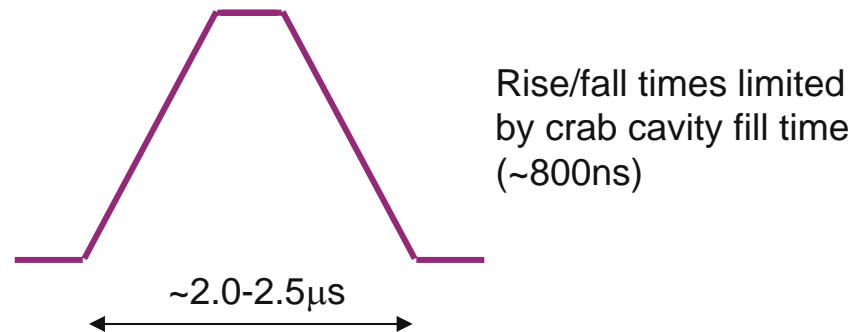


# Hybrid Fill Pattern and Chirp Timing

Hybrid fill pattern



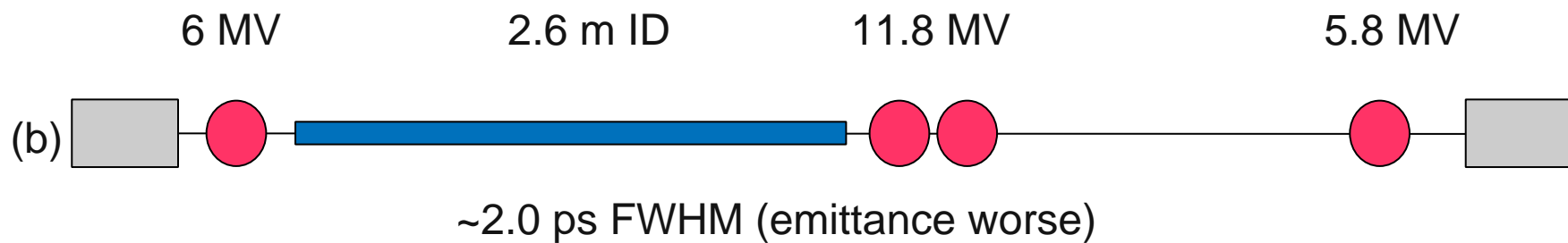
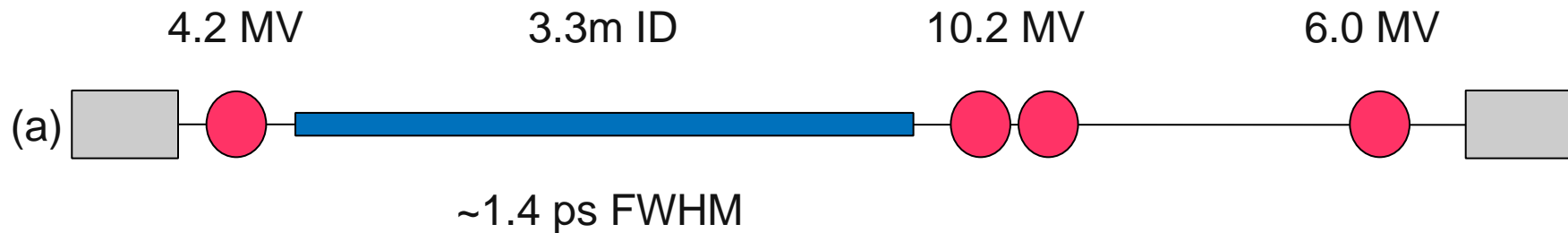
Crab cavity RF envelope



J. Carwardine

## Phase II: Upgrade Path

Extended (7.7m) long straight section



← 7.7 m →

M.Borland

# Timetable

## Sept 2007:

### Phase I:

Implement 120 Hz rep rate and 3 ps pulse length

## Sept 2008:

### Phase II:

Increase rep rate to 1kHz

- Two new klystrons, new modulator

Shorten pulse length to ~1ps

- Long ID straight section
- Reposition crab cavity structures

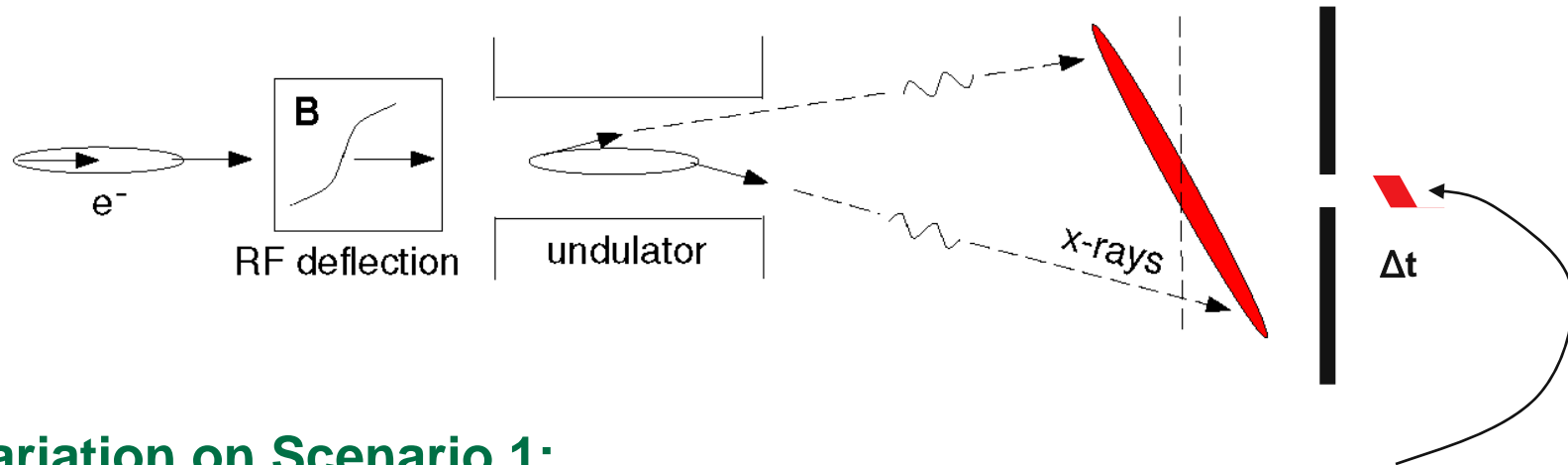
Increase photon flux

- Install long undulator

## 4. Beamline Optics

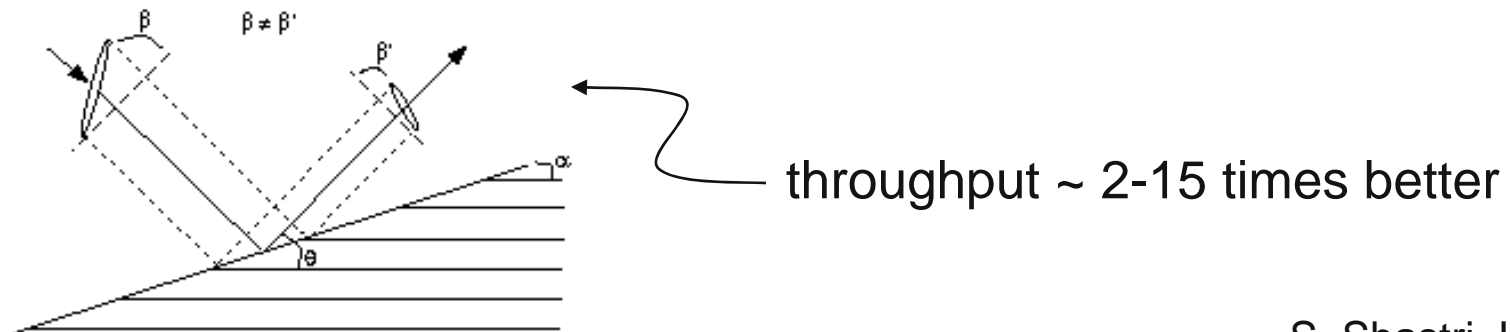
### Scenario 1:

Slits only



### Variation on Scenario 1:

Slits plus asymmetrically cut crystal

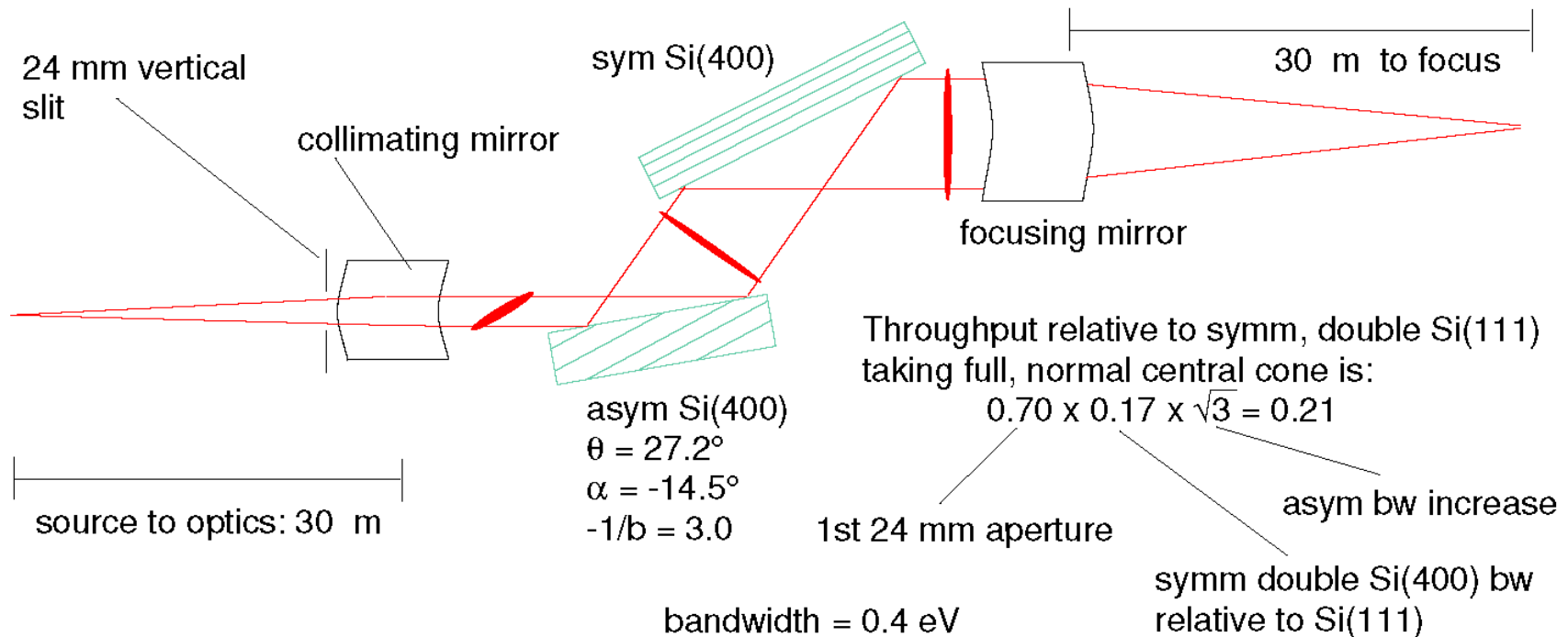


S. Shastri, K. Harkay



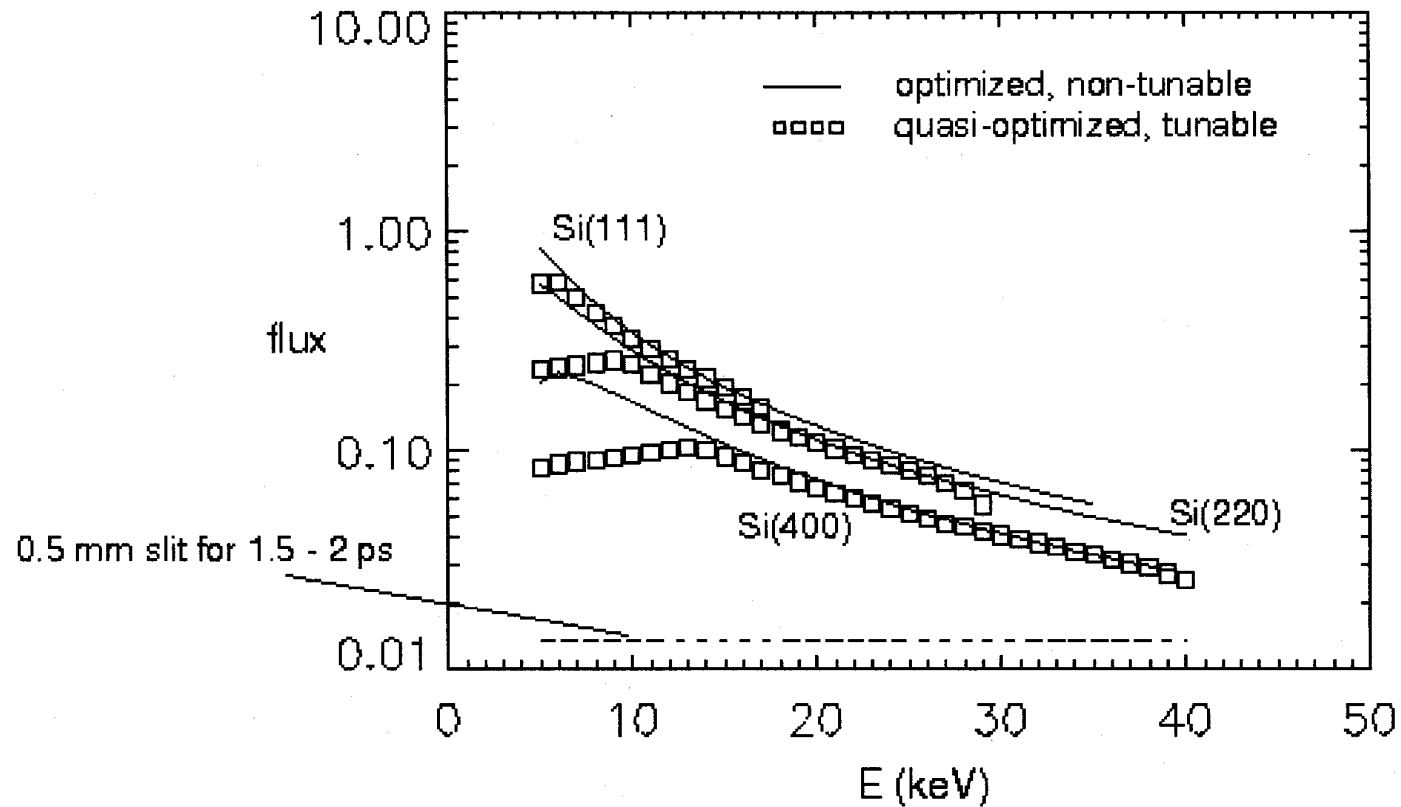
# Beamline Optics, Continued

## Scenario 2: Mirrors and Crystals



S. Shastri, R. Dejus, L. Assoufid

## Flux Comparisons



Using slits only, flux reduced by a factor of  $\sim 50$

S. Shastri

## Next

# Implement picosecond capabilities in Sector 7

## Step 1:

Low pulse rate (120 Hz, Phase I) and limited accessibility of the running mode

– Plans for the first year with 120 Hz beam:

- *Commission the short-pulse instrumentation*
- *Develop synchronization protocols*
- *Beam diagnostics for accelerator improvement and experiment apparatus*
- *Suitable detectors: x-ray streak camera for laser-x-ray time stamping*
- *Synchronize laser and the short x-ray pulse with 1-2 ps jitters*

⇒ Preliminary experiments possible with 120 Hz

## *After Step 1*

### **Step 2 (May coincide with Phase II implementation):**

Develop beamline instrument for short-pulse operation

- Suitable undulator (tunable in the 6-15 keV range)
- X-ray optics (focusing, shutter)
- Efficient detectors
- Lasers

Developing Troika-type beamline to maximize the use of the short pulses

- Station 7-ID-D for mono or wide-bandpass beam experiments
- Station 7-ID-C for monobeam experiments

## *Work in Progress*

- **R&D effort on CW cavities**
- **R&D on beam compression optics and its implementation**
- **Simulation studies: effect of beam chirping on emittance**

## **Conclusion**

***Implementation of fast track picosecond capabilities in Sector 7 BEFORE the planned upgrade makes sense:***

- ***Scientifically exciting***
- ***Technically feasible***
- ***Economically reasonable***
- ***Sociologically acceptable***